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# **DISPLAY OPTIONS FOR DISMOUNTED INFANTRY: FLEXIBLE DISPLAY CENTER HUMAN FACTORS PRELIMINARY USER SURVEY**

by  
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Natick Soldier Systems Center  
Natick, Massachusetts 01760-5020**

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14. ABSTRACT The present survey was designed to obtain sample user judgments about information display alternatives for infantrymen. The survey was conducted during a Future Force Warrior (FFW) On-The-Move (OTM) exercise at Ft. Dix, NJ in 2006. Soldiers using prototype displays (HMD and PDA) ran simulated combat missions and were then interviewed about the design of displays for tactical operations. The results are preliminary considering the limited number of Soldiers interviewed. However, recommendations given incorporate judgments from experts as well as findings from previous studies. Comments collected are paraphrased statements of participating Soldiers, the OTM staff and experienced onlookers. Summaries are grouped by key questions (i.e. Do all Soldiers need a display?). The major recommendation is that displays and display devices need to be designed for the tasks and responsibilities of key users. Specifically, leaders need larger displays for team planning and unit-team communication while riflemen need smaller hands-free wearable individual displays for quick reference but more limited operational use. Specific recommendations for optimal size, shape, and weight are presented in the report.																						
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## PREFACE

The Flexible Display Center (FDC) at Arizona State University was tasked by Future Force Warrior (FFW) management to develop display demonstrators (prototypes) for the Capstone Demonstration in FY07. The US Army Natick Soldier Center (NSC) and the US Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED) were employed by NSC Program Management to execute a human factors user survey of display forms for dismounted operations. This work was performed under Contract Number W911NF-04-2-005 during the period of December 2005 – August 2006.

The plan for the present survey was designed to obtain user evaluations of display form factors during the FFW On-The-Move (OTM) exercise at Ft. Dix, NJ in July 2006. The OTM Soldiers were given functional prototype displays (HMD and PDA) during simulated missions thus providing them with experience using these information displays for tactical operations.

At Ft. Dix, an NSC/HRED interview team (I-team) observed and interviewed OTM testers and user experts. Thus, Soldiers, FFW and support personnel of the OTM were interviewed and asked their judgments on the functioning and the design of displays used. Further, they were asked to consider improvements and alternative designs options.

The results are presented as summary statements that address the use and design of displays for Dismounted Infantry Soldiers. Paraphrased answers to questions posed are grouped by key issues. Considering the question of who should have a display, most respondents suggested that all Soldiers could use some type of digital display. However, it was also pointed out that the shape, size, weight, and content would differ depending on the Soldier's tasks and responsibilities. As to where it should be mounted and its size limit, many felt displays should be designed so the Soldier had several options for placement during use and it should be easily storable in a cargo-size pouch or pocket, or mounted in multiple locations. Leaders could use larger displays with staff/team, while squad members could use displays with comparable or smaller size, shape, and weight specifications as those commercially available. All displays must meet military standards for ruggedness and durability.

One of the key features or requirements most requested besides durability was low power consumption, i.e., long running times without recharging or battery replacement. For field use, displays need to be readable in all light conditions from bright sun to diminished light and usable with Night Vision Goggles (NVG) without backlighting. View orientation should be switchable between portrait and landscape modes. Display size limits are related to job tasks with large displays for multiple viewers and small PDA size for individual use as suggested above. All displays must be small for storage. Large displays should fold into a flat thin pocket-sized shape.

Input/Output issues include a desire for hands-free capability (e.g., voice control) assuming reliable and robust function. The next best alternative would be one-hand

operation. Touch screen and easy-to-use button and wheel controls are also seen as requirements. And finally, devices need to be operable with protective hand wear.

In summary, any use of a digital display, regardless of placement and design, should occur only in circumstances where threats are not imminent. Thus, for the rifleman, the display device should be small and storable until circumstances allow viewing the display safely. For leaders in a platoon, this caution may not apply as often. In any case, the design of displays must take into account the users' tasks and responsibilities. While specific recommendations on size, shape, and weight are offered in this report, there is a need to maintain recurring surveys to determine the optimal specifications of displays for representative users.

## ACKNOWLEDGEMENTS

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# **DISPLAY OPTIONS FOR DISMOUNTED INFANTRY: FLEXIBLE DISPLAY CENTER HUMAN FACTORS PRELIMINARY USER SURVEY**

## **1. INTRODUCTION**

In cooperation with the Army Future Force Warrior (FFW) Chief Architect and Program Management from Natick Soldier Center (NSC)\*, the Army Research Laboratory (ARL) Cooperative Agreement Manager tasked the Flexible Display Center (FDC) at Arizona State University (ASU) to develop display demonstrators (prototypes) for the FY07 FFW Capstone Demonstration. This event provides a showcase for contractor-tested prototype systems that are typically at an Integration Readiness Level 4 and a Test Readiness Level 6.

To develop user specifications for these display demonstrators, expertise from the Natick Soldier Center (NSC) and the Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED) was employed by NSC Program Management to execute a user survey of display forms.

On the multidimensional battlefield, the Army Warfighter will require extensive situation awareness (SA) that will require Soldiers to be fully integrated into the battlefield information flow. This capability will require the Warfighter to know, to a much higher degree of precision and reliability than currently available, their own location, the location of team members, and the location of other friendly forces (e.g., re-supply points, casualty collection point, coalition forces, etc.), enemy locations as well as noncombatants. Warfighters must have the ability to physically and mentally 'see' the battlefield with greater fidelity in all light, weather, temperature conditions, and manmade obscuration. They must also be able to rapidly transition across these varied conditions under extreme conditions of stress. The development of a lightweight, low-power, rugged flexible display will help meet these requirements.

## **2. BACKGROUND**

### **2.1. FFW/FDC User survey NSC (December 2005)**

To obtain preliminary user (Soldier) feedback on display features, an initial focus group was conducted to sample preferred display size and resolution attributes from users. Six liquid crystal displays (LCD) of various sizes ranging from 3.8 to 12.1 diagonal inches and resolutions (QVGA to SVGA) were used to display a series of images provided by GDC4S that were representative of actual field information content. The FFW TPO also provided the following input regarding features for the types of information expected to be presented on display devices.

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\* Recently renamed Natick Soldier Research, Development and Engineering Center (NRDEC).

- **High Resolution Graphics** for mission Situation Awareness, Positioning and Navigation for small unit operations
- **Low Resolution Text** for communications, medical support functions and memory jogger applications (i.e., on-the-spot tactical refresher training)

The FFW Chief Architect assembled a panel of 10 Army personnel (including sergeants, captains, and experienced Soldiers) at the US Army Natick Soldier Center to view nine tabletop display projections (see Table 1 below) of various sizes and resolution and respond to a rating questionnaire. Features evaluated included clarity and readability of text, maps, photos, color and brightness. Statistical paired (dependent) t-tests were computed on mean rating scores for each question comparing mean ratings for each display against each of the others. The results show the highest preferences were for the highest resolution displays. Table 2 below shows Display 6 was rated significantly higher on Overall Judgment of the display over all other displays. Display 5 was rated higher than Display 1, while the statistical tests show Display 2 was interestingly rated higher on average over Display 1.

Table 1. Display qualities evaluated

<b>Displays 1&amp;2:</b>	<b>QVGA 320x240</b>
<b>Displays 3&amp;4:</b>	<b>VGA 640x480</b>
<b>Displays 5&amp;6:</b>	<b>SVGA 800x600</b>

Table 2. Statistical comparison of rating for six displays for OVERALL judgment of displays

paired-t df = n-1 = 9						
p values						
display	1	2	3	4	5	6
1		0.018	ns	ns	0.005	0.001
2	<b>-1.060</b>		ns	ns	ns	0.001
3	-0.950	0.100		ns	ns	0.000
4	-1.250	-0.200	-0.300		ns	0.003
5	<b>-1.850</b>	-0.800	-0.900	-0.600		0.002
6	<b>-2.650</b>	<b>-1.600</b>	<b>-1.700</b>	<b>-1.400</b>	<b>-0.800</b>	

After viewing the displays the panel gave general input on what they would like to see in the body-borne display for an infantry/rifleman application. Data analysis show that for this sample of users the largest size (12.1-in. diagonal) SVGA display (resolution = 83 ppi) was rated the highest performing on every parameter. Based on group

discussion it was concluded that a form factor of less than 3.8 inch would be too small. The Soldiers preferred graphic content over text but suggested the content of the display is dependent on the operator's job tasks and responsibilities within the platoon/squad (e.g., leader vs. rifleman).

Since this initial survey was conducted independent of a specific context, results were used to draft a follow-on survey of Soldiers who would evaluate display design for specific mission and responsibilities. A new questionnaire and interview question set were developed for use in a field survey of display options for specific infantry tasks and roles (e.g., reconnaissance vs. assault, and squad leader vs. riflemen).

The survey team also obtained guidance from FFW on previously considered dismounted display design factors. These were presented as Soldier applications and *desired* features of information displays and include selected operational requirements.

#### Displays for Rifleman:

- Hands-free operation or body-worn
- Pixel Density to allow 1 km block view with 800 m target area.
- Pixel Format: 800 x 600
- Daylight and Nighttime viewability
- Refresh Rate: 1 frame per 4-5 min. (vs. video rate of 60 frame/sec)
- Illumination: 1 nit – 100,000 nit (direct view on white sand at night)
- 3-color minimum
- Lithium Battery (common type battery)
- System Modularity (for task-tailoring, replaceability, upgrading)

#### Displays for Commanders :

- Compact display size (8-inch form factor)
- Maintain light security (night-vision compatible)
- Group visibility (display angle of 60° vs. 10°)
- USB20 data input
- IPAC satellite receiver
- Multicolor

From all of the above considerations, a plan was drafted to conduct a survey in the field to refine display system characteristics that would be appropriate to leaders vs. squad or fire team members.

### 2.2. Background on Ft. Dix user survey (July 2006)

The plan for the present survey was drafted soon after the Natick 2005 user survey in order to obtain additional user data during the FFW On-The-Move (OTM) exercise at Ft. Dix in June 2006. The OTM team offered to provide Soldiers with experience using information displays for tactical operations.

This second survey was thus designed to gather more detailed information to assist in the design and development of the next generation of flexible displays and associated devices for Soldiers. The FFW team provided their most current display concepts as well as applications, environments and specific tasks/scenarios (recon navigation, squad movement to contact and an ambush/assault exercise). Interview questions were constructed by the HFE team from NSC and HRED with input from the FDC team. Questions were directed at determining Soldier preferences for display system/device size, shape, placement, weight and input/output features relative to operator position and mission responsibilities. Two devices were specifically considered since they were being used in these OTM exercises: a leader's HMD embedded in goggles and a hand-held PDA (TDS RECON).

### **3. OBJECTIVE**

The objective of this collaborative work is to obtain FFW end-user requirements and determine specifications to fabricate displays, and the devices in which they are embedded, that meet the needs of the dismounted Army Warfighter. These specifications will be used to guide delivery of one or more display options for demonstration at the FY07 Capstone Demonstration, but may be limited by what is doable in that time frame. In the longer term, these specifications will be refined to produce field-test ready displays.

### **4. APPROACH**

The FFW Chief Architect initially provided information on dismounted (Warfighter) applications (i.e., Rifleman Body-Borne Display, Commander Digital Assistant, etc.) and the projected required vs. desired display features. This information was used to refine survey instruments (questionnaires, interviews) for execution by the NSC/HRED team. These surveys involved scenario development of simulated rifleman/commander tasks and environments with follow-up discussion about system and display design options. The survey team was comprised of NSC/HRED human factors, system engineering and expertise for conducting user surveys and the evaluation of data. This survey is expected to help translate user and engineer comments and judgments into more detailed design specifications.

The interview team (I-team), comprised of personnel with human factors, system engineering and display expertise, obtained scenarios from the FFW team and constructed interview questions and individual questionnaires for use during and after simulated squad level infantry tasks with experienced user-operators and observers. Upon arriving, the team met with personnel who were leading the FFW OTM exercise (former and current military personnel with extensive experience in dismounted operations and highly familiar with display technologies for Soldiers). These experienced personnel, in addition to the test Soldiers, were interviewed about their observations and opinions regarding the display technologies being used during the course of this exercise.

When the test Soldiers arrived, they were given questionnaires regarding their experience using the Tripod Data Systems' (TDS) RECON PDA system. An image of the TDS RECON used is shown below. The test Soldier group consisted of one fire team ( $n = 6$ ), with only two of the riflemen using the test item during the exercises. The other Soldiers simply observed the use of the PDA and later considered how they might use it given its features. Thus, the collected ratings were insufficient for computing summary statistics or quantitative analyses. The I-team, therefore, interviewed military observers and engineers working with the Soldiers during the OTM exercises.

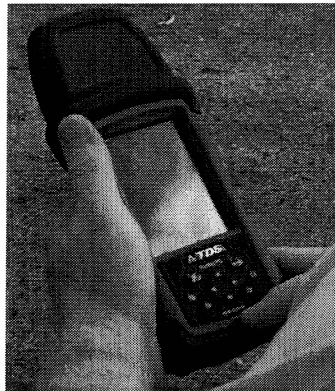


Figure 1. TDS RECON PDA system used in the Ft. Dix evaluation

After completing the questionnaire, the Soldiers prepared their gear for the exercise. During this preparation time, the I-team was given a demonstration of the PDA including its various screens and uses.

Following this, the interviewers questioned the primary software engineer about the pros and cons he had observed while the Soldiers used the PDA device. The I-team members then had the opportunity to use the PDA themselves and gain a better understanding of the tasks the Soldiers were about to execute.

The I-team interviewed several additional military observers and engineers who were in the area and who had some experience with the PDA under test. This completed the first day of observation and interviews.

The evening of the first day of testing, Soldiers were presented an FDC prototype PDA under night-op conditions. An image of the E-ink® prototype is shown in Figure 2. Experienced members and observers of the FFW team were also given the opportunity to see, learn about and manipulate the working prototype.

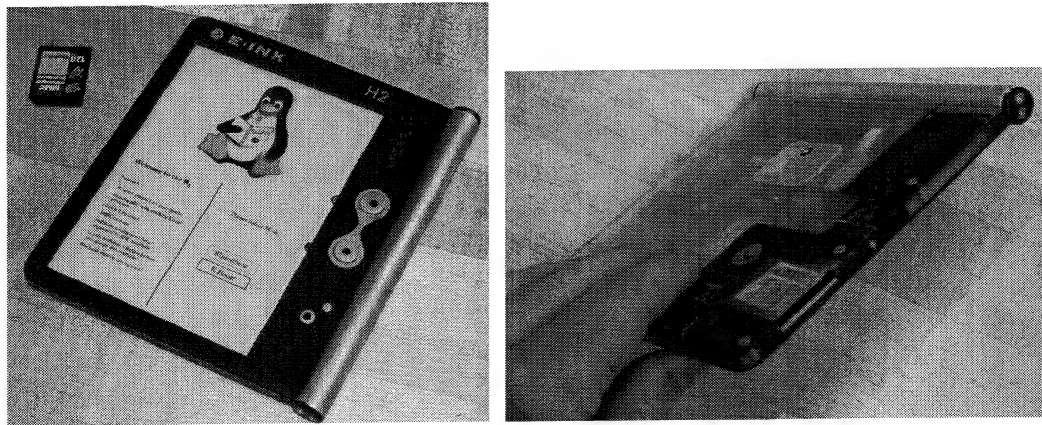


Figure 2. Front and back views of the E-ink® prototype

The following day, the I-team continued to interview all personnel who reported using the E-ink® prototype the night before.

When the test Soldiers arrived on the second day, plans and preparations were made for a test tactical squad-level operation. The squad leader was given orders by the FFW team acting as the unit's CO. The leader then conveyed that information to his team, drawing the route out on a digital map, which was then uploaded to the HMD units. The rifleman then took this same information and input it into his PDA. Normally this would have been done by two different riflemen; however, one of the PDAs was not working and could not be used. Additionally, this team was slightly smaller than a normal team (it consisted of six Soldiers). Therefore, the two riflemen would be positioned very close to each other, negating the need for two Soldiers with PDAs. The two riflemen and the two leaders who were using the HMDs were observed and interviewed as they completed their planning tasks using the electronic devices.

The Soldiers completed their training exercises (a recon, ambush, and assault). During this time they had access to the HMDs and PDA. The I-team followed and observed them as they completed their mission. During low key times, the test Soldiers were interviewed about their use of the two display devices.

At the completion of the training exercise, after a rest and clean-up break, the Soldiers and the I-team returned to the base camp. There the two riflemen and another Soldier who had previous experience using the HMD were interviewed. The two Soldiers who had used the HMDs that morning were unavailable for interview. This completed the second day of interviewing and observation.

## 5. RESULTS

The results presented here are paraphrasings of responses from interviewees and observations from the I-team. The following paragraphs summarize the views and observations obtained regarding the use and design of displays for Soldiers. These are

grouped by key questions (i.e. Do all Soldiers need a display? Where should the display be placed for use? What are the ideal or optimal size and weight features for dismounted operations?).

#### *5.1. Who in a rifle platoon/squad should have a digital display?*

Soldiers and FFW test personnel felt that the PDA display technology would definitely be useful at a leader level for mission planning, situation awareness, reconnaissance, and route navigation. They also felt that it would be useful at a Rifleman level.

Some of the FFW test personnel commented that a rifleman would not need the same level of capability as the leaders would. In the situation of the rifleman, it would most likely be used for planning, mission changes and as a backup device in the case of emergencies, such as the loss of a leader or when given new coordinates. Additionally, a PDA display would allow the rifleman to confirm his understanding of the mission plan to his leader. One observer (MAJ, USA) commented that if the leader had the information, that was enough and that by giving the Soldier everything, it would only serve as a distraction. He felt that the technology should be “capable down to the Soldier level, but is only necessary down to the team leader level.” One of the Soldiers agreed, commenting that “the PDA is helpful at the rifleman level, but is not a requirement.” Another Soldier said that most of the time he didn’t have to use the PDA, and that he shouldn’t have to use it – really it is just there as a backup. He continued on to say that a rifleman’s main job is security; the rifleman depends on his Squad Leader.

If used correctly, the display technology would limit the movement of the squad, allowing them to go directly where they needed to; saving time, and potentially, lives. Using the display technology and PDA would allow them to cut out the middle man and allow the leaders to get one command distributed to the entire team. However, it was noted that this is also currently done through the communications system. A key point to be made here is that often during mission execution the rifleman’s (and other non-leader squad member’s) attention must be keenly directed and maintained on the immediate threat environment. Attention to an information display, regardless of its form (HMD or PDA), when there is potential of encountering the enemy could be fatal at the rifleman level. Since some of the leaders (company commander, platoon leader) are somewhat more removed from the action and are required to maintain contact with various levels of command, the leadership would more likely be able to attend to an information display during some phases of mission execution.

#### *5.2. Where should the display be mounted or worn? How or where should it be stored during non-use? What are some of the limits on size, shape, and weight?*

Most of the Soldiers and FFW personnel felt that any display device needed to have the capability of being stored or mounted in multiple locations on the body. Over and over, it was noted that every Soldier will have some unique requirements or

preferences and will potentially need to keep the display somewhere different. Some comments were:

- “Every Soldier is different and wants to store it in different places” – User
- “Can’t take away the Soldier’s ability to be innovative” – FFW personnel
- “Want the device to be both storable and mountable” – User

Several different potential locations were discussed, including both storable and mountable locations. During this evaluation, the PDAs were tethered to the Riflemen. It should be noted that they like this because it led to less concerns about leaving the device somewhere; however they were concerned that the tether was not strong enough and if they did forget to store the device, it would snag on a branch and become un-tethered, causing loss of the device.

#### 5.2.1. Pocket/ Pouch

One User Representative felt that a small foldable (map-like) flat display that could fit into a front or arm pocket would be ideal. It was agreed by most FFW personnel and Soldiers that anything that was storable should not be larger than that which could fit into a cargo pocket.

Some liked the concept of something stored in a pocket or pouch, because it allowed the Soldiers to continue their mission as if they did not have the display. Additionally, it allowed them to store the device when not being used.

#### 5.2.2. Arm-Mounting

One Soldier commented that he would like a device that was mounted on his arm, similar to the concept of a map in a plastic bag that is then attached to his inside forearm. This would allow him to see it while he was sighting his weapon. The Soldiers felt that the arm would be a good place to mount the device if it was just being used for monitoring. They felt the screen would need to be about the same size as the current screen on the PDA to be effective in this position. A test Soldier also commented that an arm-mounted location would be ideal since it critically allows both hands to be on the weapon.

#### 5.2.3. Chest (Mounted or Stored)

There were two options for the chest location. One was to store the device, potentially in a pouch or between the chasse and the chest. The second was to affix the device to the outside of the chasse itself. One of the Soldiers did store the PDA between his chassis and chest at the beginning of the exercises. It was later moved to a different location. There was also group discussion regarding mounting the display on the chest. The Soldiers felt that this would be useful if you had to interact with the device. However, there was some concern expressed about reserving critical space on the chest for ammunition.

#### 5.2.4. Head-Mounted Display (HMD)

One User Representative liked the idea of a head-mounted display because it allowed the Soldier to use the device while they were on the move. He did note that it might require the Soldiers to slow down their rate of travel but would allow them to continue moving. He also noted that this would be dependent on the Soldiers ability and the terrain being traversed. In general, the leaders felt the HMD worked well; however, they did experience problems with the goggle-mounted display. The main problem was fogging. This happened even though the goggles incorporated mini-fans to help remove moisture. One Soldier complained that sweat tended to pour into the goggles. It was suggested that a sweatband be incorporated. However, based on observation, even if the fogging problem were solved the issue with using a HMD during assault like missions means attention to the immediate environment is diverted to the display. While enhancing Global SA there may be some loss of Local SA. Even though this display is being considered for leaders, the HMD form factor needs to be looked at critically for on-the-move dismounted operations.

It was difficult during the observation of the ambush exercise to determine when the leaders were using the head-mounted display and when they were looking through the goggles. Due to circumstances, the I-team was unable to speak with either of the two leaders of this mission immediately following the assault exercise. Instead, some of our questions were directed to rifle team members and test observers.

#### 5.3. *What are some key features of a Soldier's display device?*

Many of the FFW personnel had the opportunity to examine the e-ink™ prototype low power reflective display and felt that it was clear and easy to see. However, some commented that the smaller icons and detailed pictures, small lines, and small text were difficult to see on the screen in spite of its good contrast. Because of this, it was suggested there should be a “zoom” feature. This would also be needed when used with night vision goggles.

One User Representative commented that he had seen a good example of zoom capability on another device (although he did not state what that device was). He stated that it had one button, which the user pressed to make the image zoom and then they pressed it a second time to change the image back to its original size.

It should be noted that the RECON PDA was more difficult to see. The testers were not able to use it with Night Vision Goggles, however, during the daytime, under a tent on an overcast day; it was somewhat difficult to see the screen, especially if multiple people were trying to look on at once.

Some other features suggested included:

- The ability to have the last image stay on the display, therefore if the map display malfunctioned, the user would be able to see the last location on the map
- Some sort of key lock feature should be installed, so that buttons or touch screen do not become accidentally activated while the device is stowed or not being used. During this evaluation, this was a problem on the PDA. The buttons would get pressed while the device was being stored and it would open multiple applications, which would then slow down the processor. (Note: there were some difficulties with the processor speed anyway due to interactions between the software and hardware) However, having these applications open did not drain the battery.
- The need to have picture taking and sending capabilities (similar to cameras on cellular phones). High resolution is not critical but some telephoto capability would be important.
- Low light viewing without a backlight.
- Availability of checking or reviewing symbols to determine if they were reading and interpreting the map correctly.

#### *5.4. Does display size relate to job tasks? What is too small or too large?*

The size of the display will depend upon the role of the users, the individual, and the mission they are completing.

Most of the users felt the tablet laptop used by the leaders in this evaluation was too large and bulky. It had to be held by at least one hand and therefore did not allow the Soldier to use his weapon with both hands. One observer commented that the tablet was, for the dismounted Soldier, “useless in this current size; however, it is good for tracking while in the vehicle.” When commenting on optimal display size, one Soldier said, “in combat, nothing is too small.”

One of the User Representatives suggested using size 5”x7” or 8.5”x11” since these were the sizes that Soldiers were used to working with. He thought that the leader should have something a little larger than the PDA so that he could use the display to show his squad information and allow for a common view during briefings.

Interviewed Soldiers and FFW Personnel also felt that the RECON PDA device was too large and bulky; however they felt that the screen size was okay for the rifleman role. Most felt that the PDA needed to fit comfortably into a pocket.

### *5.5. What are some of the Input/Output issues for dismounted operations?*

There were two overarching opinions regarding the user interface and operation of a Soldier display. First, Soldiers need to be able to interact with the device without removing their hands from their weapon. If impossible, then one-handed operation would be the next best option. The second opinion was that the Soldiers would only need to use the display, for the most part, when they were stationary.

Multiple options for interacting with the display were discussed.

#### **5.5.1. Wheel & Buttons**

Soldiers liked the idea of using a wheel to interface with the display. They were already familiar with the “wheel” from the HMD. The idea of a finger or thumb wheel similar to that on a blackberry was discussed and generally liked. This would allow the user to scroll through the different menu options. It was noted that handedness might influence the position of the wheel if the device is held and operated with one hand. In general, the position of the wheel and buttons and other physical features would need further investigation.

As noted above, the buttons that were on the RECON PDA needed to be locked to inadvertently keep them from being activated. This malfunction slowed down the menu operation and required the user to waste time shutting down unwanted selections.

After examining the e-ink prototype reader, users reported being able to see the input buttons while wearing the Night Vision Goggles and one observer stated that he was able to use the buttons to operate the device with one hand. While there was some concern expressed over the ability of users to operate the buttons with a gloved hand, no one seemed to have any difficulties operating the display under no-light conditions.

#### **5.5.2. Touch Screen/ Stylus**

Those interviewed believed that the touch screen would work well in the field, although there was no clarification whether this would be done with a pen device or finger. The PDA used in this user survey had a touch screen keyboard that worked sufficiently; however, the testers observed that each key was very small and it appeared to be difficult to use with the finger.

The small point of the stylus was able to navigate these small keys better and the Soldiers had no problems using the stylus to operate the device. It was noted that the stylus had been tied to the PDA to prevent it from getting lost. Several users commented on the likelihood of the stylus getting lost resulting in an inability to use the device. There was some concern expressed that using the stylus would take the users hand away from their weapon.

### 5.5.3. Voice Command

Several Soldiers felt that voice command would be the ideal interaction format. Voice command would allow the user to interact with the device without removing his or her hands from their weapon. These Soldiers, apparently, were not concerned about giving away their position since they only used it while they were stationary. It was also noted by the testers that during the ambush mission the leader often gave orders using either the communications system or by talking to other members of his squad. The verbal commands were much quieter than the level of noise they were creating by walking through the brush and did not increase their chances of being discovered.

### 5.6. *What are some of the battery power issues?*

Users had lots of concerns about battery life. They wanted something that would last a long time (e.g., 72+ hours) and use common batteries readily available in the market place (such as AA). Respondents commented that they were impressed with the e-ink's ability to run on AA batteries and that they felt positively about the low levels of power consumption used by the prototype. One User Representative also commented that he liked the fact that he could use the device without a backlight, because this would save battery life. Battery life is one of the most important factors in determining user acceptance and the successful application of any display device for dismounted operations regardless of form.

### 5.7. *What are the important compatibility issues?*

The displays were only tested with the FFW equipment; compatibility was not a primary focus of this evaluation. There were only two compatibility issues raised by the Soldiers and/or the FFW personnel. First, User Representatives wanted to make certain that the device would be usable with gloves, especially in regards to interacting with the device (such as with buttons, wheels, etc.).

A Soldier commented that when he was wearing the laptop in his pack while lying in the prone position, it would push his helmet up and move his Night Vision Goggles. This obviously made it difficult for him to fire his weapon.

## 6. DISCUSSION

### 6.1. *Who in a rifle platoon/squad should have a digital display?*

It is recommended that both leaders and riflemen have some type of visual information display for enhancing unit performance. The leader's display system should certainly have more expanded capabilities than the rifleman's. What these capabilities should be needs to be further explored and may be somewhat dependent on hardware and

software capabilities. Display capabilities for leaders should focus on leadership functions such as mission planning, intelligence reports, resource allocation, whiteboarding, command and control of squads, communication with higher echelons, and coordinating reconnaissance operations. Specially designed displays would allow leaders the tools to make planning and control of their unit's mission easier. It would also allow for changes to be made during the middle of the mission with little work necessary to update the plans. It should be noted that this evaluation did not look at distinction in the capabilities at different echelons. This should be looked at in the future. Elliott and Heller found similar results when assessing the Warrior's Edge technology in the 2004 Horizontal Fusion Technology Demonstration.<sup>1</sup> In their study, they found that most participants agreed that only team leaders and above needed PC tablets.

Riflemen capabilities should focus on pre-assault mission rehearsals, tactical (non-text) situation maps and allow the user to occasionally communicate with their leader in simplified or symbolic format. This will allow them to have the information available as a back-up, in the case where the information is not available from the leader. Additionally, it will allow them to exchange information with their leader so both are aware of the latest situation.

*6.2. Where should the display be mounted or worn? How or where should it be stored during non-use? What are some of the limits on size, shape, and weight?*

Overall, it is recommended that whatever form the display takes, it should be flexible enough that it can be positioned in multiple locations, both on the body and in storage. This will allow Soldiers to use the device in the location that suits them and their individual duties within the unit most efficiently.

**6.2.1. Pocket/ Pouch**

Any display that is created should, ideally, fit into any of the Soldier's uniform pockets; whether this is through folding/ bending or the device's full size. This will allow users to store the device when it is not needed, helping to protect and further increase the life of the device (think of a flat and larger version of the clam-shell cell phone). This would allow for an alternate location for use or storage, if mounted. Additionally, it will keep the device out of the user's way and allow them a place to put other equipment, if needed.

**6.2.2. Arm Mounting**

An arm-mounted display is a viable option for the riflemen. Ideally, the same device could be mounted in multiple ways (excluding HMDs), be it either to the arm or chest (the straps could be different). Below are some photo examples (Figure 3) of arm bands used for consumer portable music players and a conceptual armband developed by the FDC (Figure 4). Further investigation into the design is necessary since the device placement should consider the physical-visual dynamics of the task.

The Soldiers interviewed in this evaluation indicated that they would prefer to wear the device on their inner forearm, so they could continue to keep their hands on their weapon and still monitor or view the screen when necessary. In this case, the display would have to be limited in size and would need to be rather thin (at most .25-.50 inches thick). It is recommended that the screen be no smaller than the screen on the PDA used in this experiment (approximately 3 inches by 2.25 inches) based on the previous user survey. However, display size might have to be reduced slightly to optimize the fit across population anthropometry of the lower arm.

One report for FFW commented that a forearm mounted PDA may not allow for enough text to provide as an embedded training platform. Anthropometry should be used to determine if military forearms will allow for a large enough screen for the necessary features. This report also noted that a forearm mount must allow the user to accommodate for glare. Another consideration with a flexible display is sculpting the device to the user's arm with padding or molding.



Figure 3. Three armband systems sold commercially

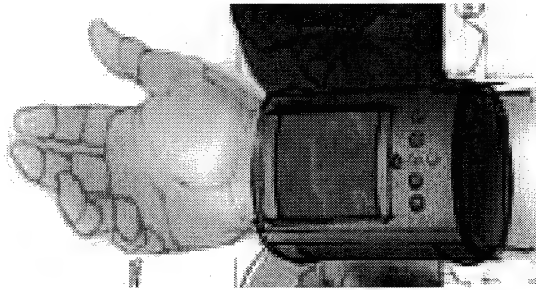


Figure 4. Conceptual wrist-mounted display by FDC

#### 6.2.3. Chest Mounted (or Stored)

One idea is to have a storage space on the chest. This location is convenient for the user to remove and use the device, perhaps, also on the chest. Since this space is not currently being used by most Soldiers, there would be no need to rearrange other items. The ballistic protection of the chaste should be tested to make certain that blocking that space does not degrade its integrity. Additionally, durability of the device in this location needs to be reviewed.

If the device were mounted on the chest, it could still allow for easy viewing and interaction. In this case, there would need to be a way to “flip” up and down the screen when it was needed. A downside is that it may displace other equipment. This would have to be a user’s or unit leader’s choice and may be a more viable option for leaders than for riflemen, since leaders will need to interact with the device more often.

#### 6.2.4. Head-Mounted Display (HMD)

We should continue to evaluate if the HMD is a viable option for the leaders as it is currently being used. Not enough information was gathered by the I-team during this evaluation to make any recommendations on this form factor.

It should also be noted that Elliott and Heller found that several Soldiers liked the HMDs because it provided them with additional situational awareness.<sup>1</sup> More study is needed to determine if this is actually true or only what they perceived.

M.R. Fletcher measured workload with different types of displays.<sup>2</sup> She showed that HMD and arm screen information displays increased the user’s mental workload. It is not surprising when considering that with HMDs the user is trying to monitor two things at one time (if they wear the display down all the time) and if they do not or if they need to monitor their arm, the addition of the movement to position the display in a visible location potentially creates this additional workload. It is likely that chest mounted displays and any type of stored displays would have similar problems. However, it is unclear if this would still be the case if the user were standing stationary. Fletcher’s research recommends using audio to convey necessary information, but it is unclear if this would generalize to the types of information (especially maps) that were being conveyed in this user survey.

#### 6.3. *What are some of the key features of a Soldier’s display device?*

Based on this evaluation, the following features are recommended to be incorporated into either the software or hardware:

- Night vision and light security. Device should not use backlighting and display should be viewable with night vision goggles.
- A zoom feature to allow user to increase the size of individual objects on the display screen. This will aid in vision under low light levels and with Night Vision Goggles. This capability should be simple to use, requiring as few steps as possible to zoom in and out. FFW MANPRINT Analysis report agreed that a zoom feature was needed.<sup>3</sup>
- The display information should be visible in the day and night. Leader displays should be visible from a variety of angles as well. Riflemen displays should be visible at the appropriate angles of regard while using his weapon or other equipment (e.g., inner forearm while aiming weapon).

- Low power usage and common battery. It is extremely important to have a display device that does not require frequent charging or battery replacement. The battery should be a common type like AA or AAA.
- The display should be able to hold its last display without using power. Therefore, if the image is damaged, the user will still have access to the latest map/information, and will be able to complete the mission.
- If buttons or touch-screen interfaces are used, there should be an easy way to lock and unlock the device (similar to a cell phone) to avoid accidentally activating buttons and controls.
- A camera, similar to cell phone technology, should be incorporated into the device. This would allow users to photograph and document the information during reconnaissance and send information to their leaders or team members. The camera should be small and will not require large pixel capabilities.

#### 6.4. *Does display size relate to job tasks? What is too small or too large?*

For the PDA the display should be no smaller than a 4 inch diagonal, assuming device size allows this. Ideally, the display would fill almost all of the face of the device (see Figure 5).

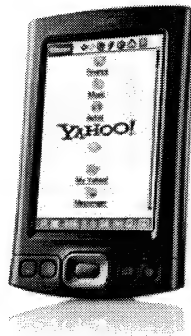


Figure 5. Example of a PDA that uses the majority of its face for its display

The depth (thickness) of a device this size (approximately 5" x 3") should be no more than 0.5 inches at its widest part. The shape of the device should be tapered to allow for those with different size hands to still hold the device securely.

The leader display should be larger than the rifleman display. This display needs to accommodate multiple viewers simultaneously. Each observer needs to have a clear view of the information presented on the screen so they are able to easily comprehend the content and aid in mission planning. Suggested sizes to look at for the leader display device are 5x7 inches and 8.5x11 inches, since both are standard

sizes currently in use and provide effective tactical map displays. Ideally, these would be able to fold or roll up so that they could be stored in a pouch or pocket. Ideally, the folded device would have a depth (thickness) of no more than 0.5 inches.

#### *6.5. What are some of the Input/Output issues for dismounted operations?*

##### **6.5.1. Wheel & Buttons**

Recommend incorporating at least one finger wheel into the design of the display/device for menuing options. Ideally, the screen could be used in both the portrait and the landscape orientation and the wheel would be placed approximately in the center of the long side. This would allow for elimination of or a smaller number of buttons for interacting with the device. This would also provide a larger screen on a smaller device. The wheel will allow users to scroll through different menu options and allow the user to operate the device with only one hand. The dimensions and placement of these features need to be repeatedly tested with target users during design prototyping, taking into account tasks and operational conditions.

Buttons should be raised and allow for tactile feedback, so that the user knows when they have pressed them. The FFW MANPRINT Analysis<sup>3</sup> commented that soft buttons should be used. MIL-STD 1472<sup>4</sup> suggests buttons no smaller than 0.5” squares.

##### **6.5.2. Touch Screen/ Stylus**

Recommend the display having a touch screen that can be interacted with using a fingertip. This would require software that had icons large enough so the finger could be used to accurately interact with the device. By eliminating the stylus, the concern and cost of lost stylus is no longer a concern. Ideally, this could be integrated with a mouse or larger wheel interface if needed. However, considering potential problems with this recommendation, a stylus should remain an option.

##### **6.5.3. Voice Command**

Voice command is also an option that would be very useful for this device; however, it is dependent on the availability of good software technology that can rapidly, reliably and accurately understand user commands. This would be a more viable option for the leaders and should be investigated further as to whether it is beneficial at the rifleman level.

#### *6.6. What is the viability of the Head-Mounted Display (HMD)?*

Recommend that the HMD continue to be evaluated, to determine if it is a viable option for the leaders and to determine how it is currently being used. Not enough information was gathered during this evaluation to make any determinations. However, it should be noted that a 1997 report by the Committee on Human Factors (NRC) on Soldier tactical displays cautioned against the use of the HMD for dismounted

operations.<sup>5</sup> The main concern was that an HMD obstructed the view of the operator and diminished local situation awareness. This is the general concern of any display for the combatant who is required to maintain focus on the immediate environment and potential threats.

#### *6.7. What are the battery power issues?*

The device should use as little power as possible. The power should come from small, lightweight, and readily available batteries (such as AAs or AAAs). An indicator should provide feedback to the user to let them know when battery consumption is being used and the level of power left in the battery. Furthermore, the display should be able to operate for days (hopefully weeks), not just hours if it is going to be a viable option for infantry operations. Constant recharging or replacement of batteries would create a significant logistical burden to dismounted infantry.

#### *6.8. What are the important compatibility issues?*

The display device will need to be compatible with the FFW uniform (as well as any other uniforms and equipment) and all of its components, both physically and technologically. Flexibility is given to a design where the device can be stored and mounted on multiple locations (ideally, store in pockets, external pouches, and chest, as well as mountable on arm and chest).

## **7. PRELIMINARY RECOMMENDATIONS**

In 1996-1997 the Committee on Human Factors of the National Research Council and National Academy of Sciences conducted a study of tactical displays for dismounted infantry<sup>5</sup>. The study was sponsored by the Natick Soldier Center. The conclusions of the study included a caution about the use of the Head-Mounted Display (HMD) for this user because of the potential of an HMD interfering with Local, as apposed to Global, situation awareness. This is the same concern the FFW team has expressed for any visual information display for the rifleman. Christopher Wickens' Multiple Resource Theory would predict that certain missions and tasks require the infantryman to be cognitively and visually focused on the immediate environment.<sup>6</sup> Any use of a digital display should be used only in those circumstances where threats are not imminent. Thus, for the rifleman, the display device would be stored away until time allowed reference to the device. For leaders in a platoon this caution may or may not apply as often.

In the MANPRINT analysis report various displays for Soldiers were considered to include HMDs, notebook computer, PDA, and a wrist mounted display.<sup>3</sup> Size, shape and weight and user requirements were some of the factors considered. It was concluded that a notebook size computer display was useful for leaders but too heavy and bulky unless it was used within a vehicle. A wrist display was recommended but this type of display required special design to be lighter and fit comfortably around the arm and wrist.

Based on available information from this preliminary survey and studies cited, a reasonable hand-held display device demonstrator for a dismounted infantryman would have approximately the following dimensions and features:

Device size:	H x W x D: ~ 6.0" x 4.0" x 0.5"
Device weight:	~ 5 – 6 oz.
Device shape:	Slightly tapered sides for holding
Placement:	Variable: fit anywhere but particularly on arm-wrist area
Display size:	Approximately a 3.8" diagonal display or greater
Display orientation:	Switchable: portrait or landscape views
Display lighting:	Reflective (no back lighting) sunlight, night-vision viewing
System I/O:	Hands free or one-hand op (scroll wheel, touch screen)
Power:	Low power, common battery (AAA), rechargeable option
Special features:	Color, last screen standing, water-environment proof, indestructible, easy maintenance-repair, L-R handed option, user friendly.

The idea of a flexible display for the rifleman and leaders is one that should continue to be explored. Further study should be conducted to determine some of the finer details of the display and the associated devices. Each of the following areas should be evaluated separately:

- Software
- Physical Form
  - Storage/ Mounting Location
  - Compatibility With Clothing and Equipment
- Screen Characteristics
  - Size, refresh rate, etc.

As a follow-on to this survey, some mock-up display devices should be constructed (based on the above recommendations) along with off-the-shelf variations. Experienced users should provide their judgments on key design features and dimensions. That is, these evaluations should include some type of physical model or prototype to allow the participants to conceptually (imaginatively) interact with it in the contexts of their missions and evaluate.<sup>7,8</sup> This would allow users to give more informed and accurate responses reflecting their likes and dislikes and provide judgments about design factors that are likely to work or not work during combat mission planning and execution.

Once the above two evaluations have been completed, then the system should be evaluated in the field under more realistic and demanding operational conditions. A larger number of participants conducting a wider variety of missions are needed in order to gain some confidence in the design specifications for these users.

This document reports research undertaken at the U.S. Army Research, Development and Engineering Command, Natick Soldier Center, Natick, MA, and has been assigned No. NATICK/TR-07/007 in a series of reports approved for publication.

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Appendix  
**Sample Human Factors Interview Questions**

**Demographic/Background Information**

1. Subject Name: \_\_\_\_\_ 2. Age: \_\_\_\_\_ 3. Gender: M F
4. Rank: O E \_\_\_\_\_ 5. Years in Military Service: \_\_\_\_\_ years
6. MOS: \_\_\_\_\_
7. Handedness: RIGHT HANDED LEFT HANDED AMBIDEXTROUS
8. Do you operate weapons or any other military equipment LEFT HANDED? YES  
NO  
If YES, please list that equipment:
9. How many months or years of experience have you had in each of the following positions:
- |                          |                        |
|--------------------------|------------------------|
| _____ Platoon Leader/Sgt | _____ Fire Team Leader |
| _____ Squad Leader       | _____ Rifleman         |

10. Do you wear eyeglasses or contact lenses to read or view computer displays? YES  
NO
11. Are you colorblind? YES NO  
If YES, type of colorblindness, if know: \_\_\_\_\_
12. How frequently do you use small display screens (e.g. cell phones, games, PDA)?  
(circle one)  
DAILY WEEKLY MONTHLY LESS THAN MONTHLY
13. Did you have the RECON PDA available for your use during this training session?  
YES NO  
If YES, while you had the RECON PDA available, how frequently did you use it?  
(circle one)  
FREQUENTLY OCASSIONALLY RARELY NEVER
14. Please describe any experience you had using small display screens while in military situations prior to this training session:

### **Flexible Display – Ft Dix, NJ: Informal Interview Questions**

1. Please describe how and when you used the PDA during these activities:
  - a. How did/would your unit use a PDA in the planning/preparation stages of a mission?
    - i. What would be the best display for planning? (including size, configuration, input features of PDA vs. HMD vs. Arm-mounted display, vs. other)
  - b. How did/would you use a PDA in Movement to ORP phase of a mission?
    - i. What would be the best display for this Movement phase?
  - c. How did/would you use a PDA in the Recon stages of a mission?
    - i. What would be the best display for recon?
  - d. How did/would you use a PDA in the assault movement to contact or building clearing phase of a mission?
    - i. What would be the best display for this execution phase?
2. How did you use the PDA as an individual team member? How did your team use the PDA (indicate Squad or Platoon level)?
3. In what ways did the PDA work well for you?
4. In what ways did the PDA not work well for you?
5. What problems are there in storing and retrieving PDA during mission operations?
6. What are the pros and cons of having the PDA be mountable on the body?
7. What are the pros and cons of the following configurations:
  - a. PDA
  - b. Arm mounted (any location)
  - c. Head mounted display
  - d. Chest mounted display
  - e. Other (e.g., unfolding map-like display)

8. How would you use an information display in the role of ...
  - a. Rifleman?
    - i. What would be the best display for a rifleman?
  - b. Fire Team Leader?
    - i. What would be the best display for a fire team leader?
  - c. Squad Leader?
    - i. What would be the best display for a squad leader?
  - d. Platoon Leader/ Platoon Sergeant?
    - i. What would be the best display for a platoon leader/sergeant?
9. How did you use the PDA for ...
  - a. Navigation?
  - b. Communication?
  - c. Reports?
10. What are the major issues in using the PDA for ...
  - a. Navigation?
  - b. Communication?
  - c. Reports?
  - d. Other functions (rehearsals, memory joggers, etc.)

## LIST OF ACRONYMS

ASU	Arizona State University (see FDC)
ARL	Army Research Laboratory
FDC	Flexible Display Center at ASU
FFW	Future Force Warrior
GDC4S	General Dynamics C4 Systems (Command, Control, Communications, & Computers)
HMD	Head-Mounted Display or Helmet-Mounted Display
HRED	Human Research and Engineering Directorate, ARL, Aberdeen, MD
IPAC	Infrared Processing and Analysis Center (IPAC), NASA
LCD	liquid crystal displays
MANPRINT	Manpower and Personnel Integration (US Army Human Factors Engineering program for equipment and system development)
NSC	Natick Soldier Center (now NSRDEC)
NSRDEC	Natick Soldier Research, Development and Engineering Center (formerly NSC)
NVG	Night Vision Goggles
OTM	On-The-Move military exercise at Ft. Dix, NJ
PDA	Personal Digital Assistant (see TDS RECON PDA)
QVGA	Quarter VGA display
SA	Situation Awareness
SVGA	Super VGA display
TDS	Tripod Data Systems, maker of TDS RECON PDA
TPO	TRADOC Project Office
VGA	Video Graphics Array



